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Coupling Coefficient Calculation for Laterally-Coupled Distributed Feedback Lasers

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Abstract: Coupling coefficients were calculated for laterally-coupled distributed feedback (LC-DFB) lasers in which gratings are formed on and around a ridge. Calculations were done with coupled-mode theory applied to two-dimensional field intensity obtained with the imaginary-distance beam propagation method. Dependence of coupling coefficients on various LC-DFB laser structural factors was investigated as well as their sensitivity on processing variations.

Introduction: Recently there is a growing interest in laterally-coupled distributed feedback (LC-DFB) lasers[1]. In LC-DFB lasers, gratings are made on and around a ridge after the ridge formation as illustrated in Fig. 1. Consequently, the need for epitaxial regrowth or growth on corrugated substrates is eliminated, which is often a yield-limiting step for DFB laser fabrication. It is unlikely that performance of LC-DFB lasers will match that of conventional, more complicated DFB lasers employing buried heterostructure (BH). However, the advantage of simpler fabrication and the consequent cost reduction makes LD-DFB lasers a promising candidate for applications in which cost is an important factor. In this paper, the results of coupling coefficient (κ) calculations are presented that have been performed as a first step for realizing InP-based LC-DFB lasers.

Method of κ Calculation: For κ calculation, coupled-mode theory was used. According to coupled-mode theory, the magnitude of κ for first-order rectangular-shaped gratings is given as

$$|\kappa| = 1/(n_{eff}\lambda) \times (n_2^2 - n_1^2) \times \sin(\pi\gamma) \times \Gamma,$$

where n_1 and n_2 are refractive indices above and below gratings, respectively, n_{eff} the effective mode index of the waveguide, λ the wavelength of interest, γ the grating duty cycle, and Γ the field overlap integral with the grating region. In order to determine κ, numerical values of n_{eff} and Γ are required for a given LC-DFB structure and these were calculated with the imaginary-distance beam propagation method (IDBPM)[2]. Fig. 2 shows a generic ridge waveguide structure used for the calculation. Here, the grating region is represented by a homogeneous layer with a weighted average dielectric constant between the materials above (dielectric) and below (InP) the gratings. For simplicity in numerical calculations and in order to generalize many different active and SCH layer structures possible, the active and SCH layers were lumped together into one homogeneous layer with an effective refractive index, n_{act}, and thickness, t_{act}. Only the fundamental lateral mode with TE polarization at 1.55 μm was considered since it is most relevant for applications.

Dependence of κ on LC-DFB Structure: The dependence of κ on LC-DFB laser structure was investigated. The investigated parameters and corresponding symbols shown in Fig. 2 are composition and thickness of active and SCH layers (n_{act} and t_{act}), ridge width (w_{top} and w_{bot}), ridge side-wall angle (Θ), separation between the grating region and the active and SCH layers (t_c), refractive indices of dielectric materials covering the ridge (n_{die}), and grating depth and duty cycle (t_g and γ). κ 's for different values of above parameters were calculated and the resulting dependence was analyzed. For example, dependence of

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See, for example, R.D martin et al., IEEE PTL, Vol. 7, p. 244, 1995

S. Jungling and J.C. Chen, IEEE JQE, Vol. 30, p. 2098, 1994.

κ on ridge width is shown in Fig. 3 along with other parameter values used for the calculations. It can be seen that a narrower ridge provides larger κ and this is due to the larger lateral evanescent field intensity with a narrower ridge. Fig. 4 shows dependence of κ on the depth of etched gratings. The value of κ initially increases with the grating depth but soon saturates at around $t_g = 0.3$ µm. Clearly, these findings are very useful for determining a precise LC-DFB laser structure with a desired κ value. The details of κ dependence on other investigated parameters will be presented.

In order to make cost-effective DFB lasers, it is very important that device parameters such as lasing wavelength should not strongly depend on possible process variations. It was found by calculation that n_{eff} and, thus, the Bragg wavelength in LC-DFB lasers are much less sensitive than those in BH DFB lasers to possible ridge width variations. Details of this comparison will be presented as well.

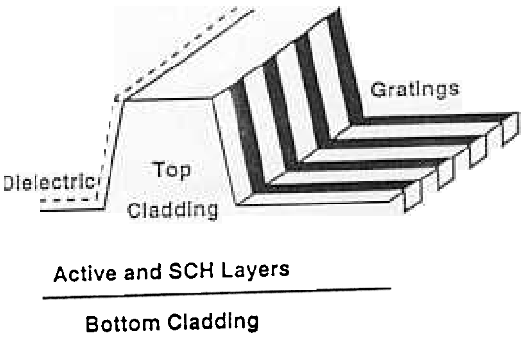

Figure 1: Schematic drawing of Laterally-Coupled DFB laser.

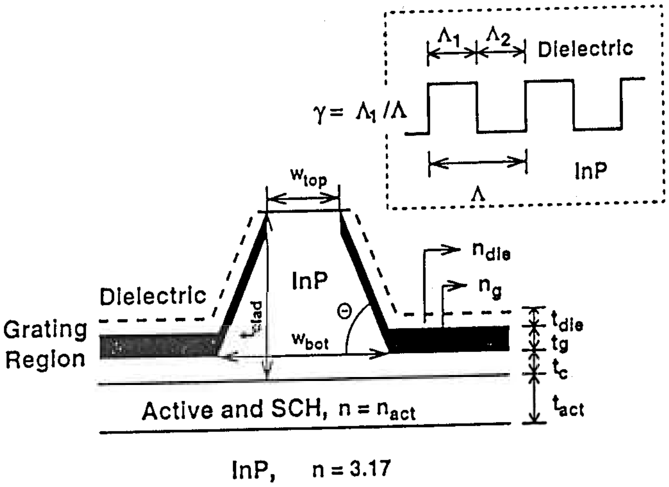

Figure 2: Generic LC-DFB laser structure with parameter symbols used for calculations.

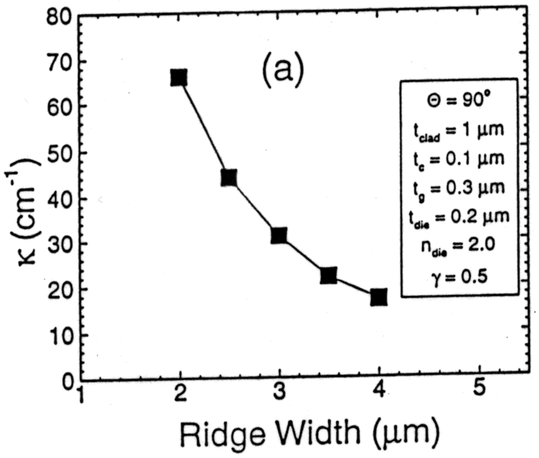

Figure 3: k dependence on ridge width.

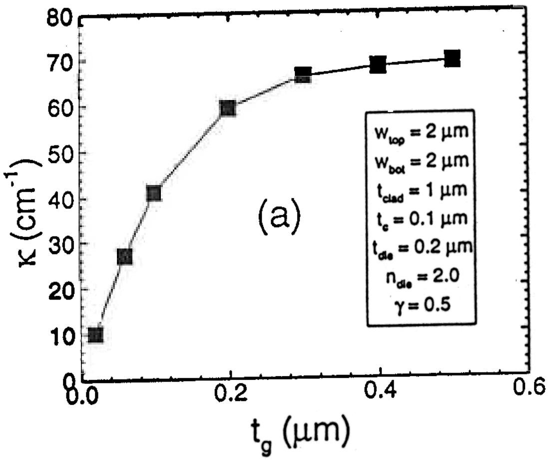

Figure 4: k dependence on grating depth.